U.S. Department of Energy
Energy Efficiency and Renewable Energy

Daylighting

Larry Kinney
Southwest Energy Efficiency Project

Overview – benefits of Daylighting

- A pleasant and appealing environment
- A natural interior environment with excellent color rendering
- Improve academic performance
- Significant energy and demand savings

Evolution of windows in classrooms

- Up until 50 years ago, most schools (and workplaces) used daylighting

Evolution of windows in the classroom

- In the late 1960s and 70s, windows were considered:
  - A distraction for children
  - An energy liability
  - A maintenance liability
  - A security liability

- The “Open Classroom” of the 1970s was often a windowless classroom, in a big, open-plan building

- “Energy conservation” retrofits have often removed daylight in an effort to save energy and reduce maintenance

- In the 1990s, many schools were overglazed

The challenge…

We want to get it…

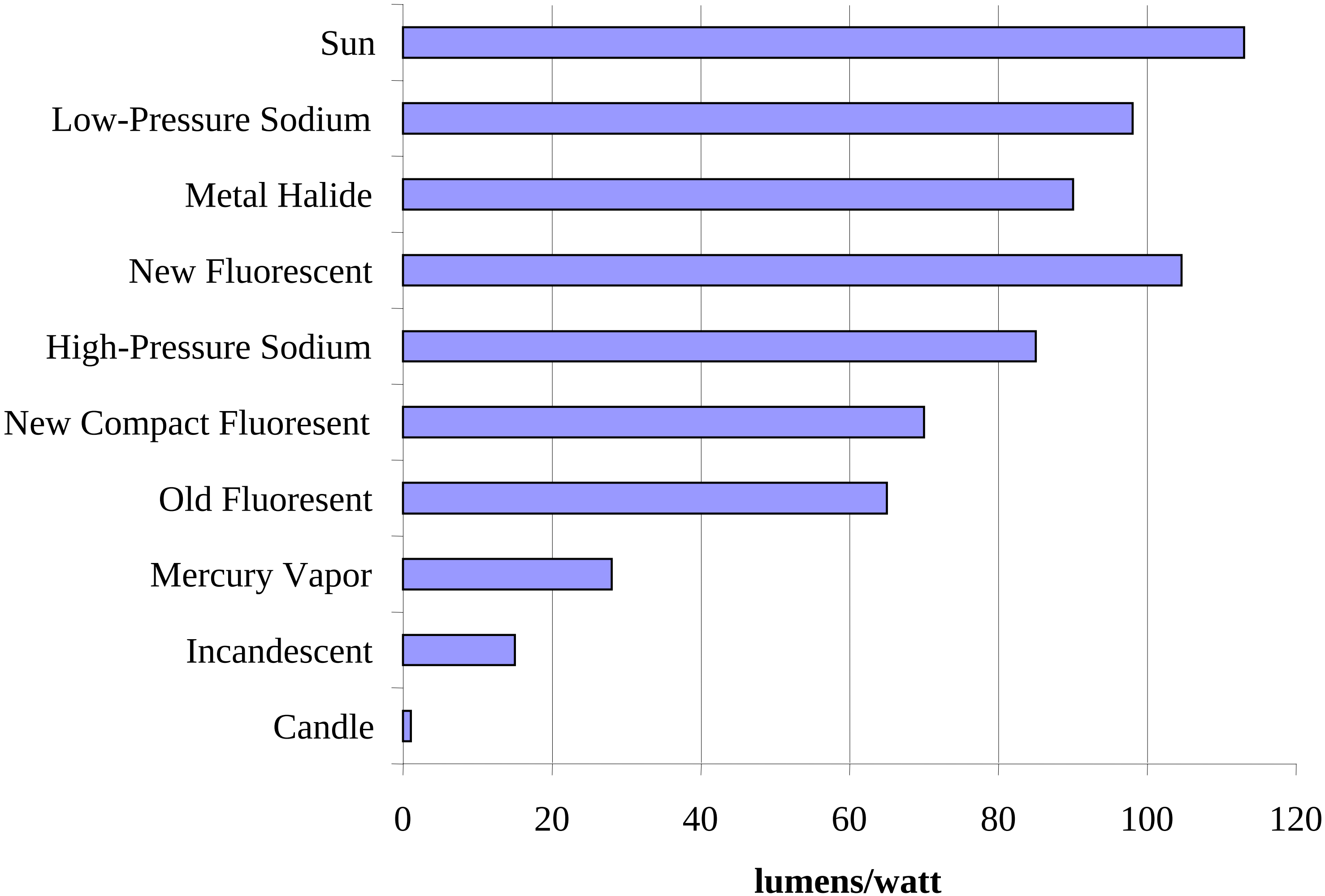
as Goldilocks said

"Just Right"

Footcandle

- The illuminance on a surface one square foot in area on which there is a uniformly distributed flux of one lumen.
- The lumens incident on a surface = footcandles x the area in square feet.

Luminous efficacy (Lm/W)



Sunlight provides more lumens per watt than other lighting

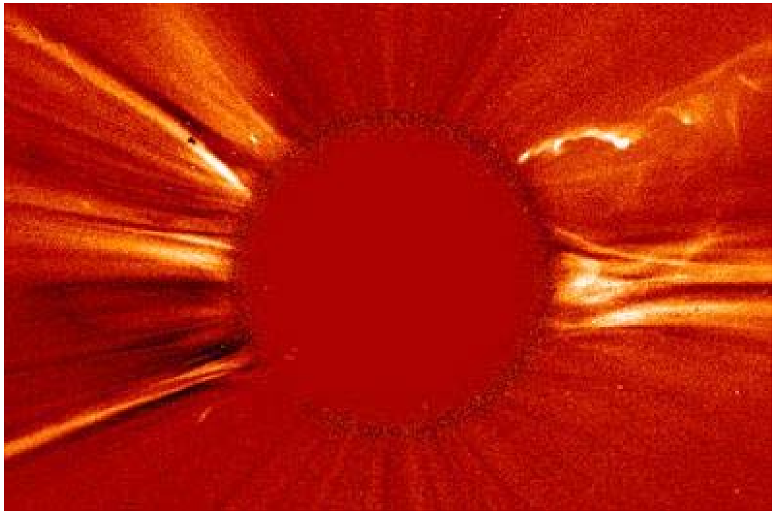
More light…

Less heat

Advantages of Daylighting

Compared to electric lighting:

- Daylighting "watts" don't make the meter turn any faster…free lighting
- Daylight is abundant when utility peak demand is high (summer days)
- Daylighting results in lower cooling consumption
- Good daylighting designs reduce A/C demand and allow for specifying smaller coolers



Fenestration terms used in Daylighting

- Visual transmittance (V_t): the percentage of light in the visual spectrum that passes through a window
- Solar heat gain coefficient (SHGC): the fraction of all solar energy (throughout the solar spectrum) that passes through a window
- Recent glazing options include fairly high V_t and fairly low SHGC…yielding more light than heat.

Key objectives in Daylighting design

- Designing spaces to use controlled natural light
  - Reduce glare
  - Address low solar angles
- Using Daylighting to provide the primary illumination within a space (where possible)
- Optimizing the use of natural and electric lighting

Daylighting design principles

- Allow **no** direct sun penetration that can fall on viewers' eyes, except in circulation spaces.
- Diffuse the light broadly through diffuse reflectors, glazing, and/or shading.
- Introduce daylight as high as possible.
- Use light-colored surfaces.
- Keep brightest surfaces out of line of sight.
- Provide blinds or louvers where there is potential for glare and for audio-visual control.
- Model to ensure optimal performance

Other Daylighting design considerations

- Natural ventilation
- Visual communication
- Noise control
- Radiant comfort - hot and cold surfaces
- Safety and security
- Air and water leakage
- Condensation
- Maintenance and replacement

Daylighting design pitfalls

- Buildings architecturally “designed” without careful attention to fenestration
- Incorrectly designed windows and/or skylights
- A building with good daylight illumination but with electric lights burning away

Direct beam sunlight

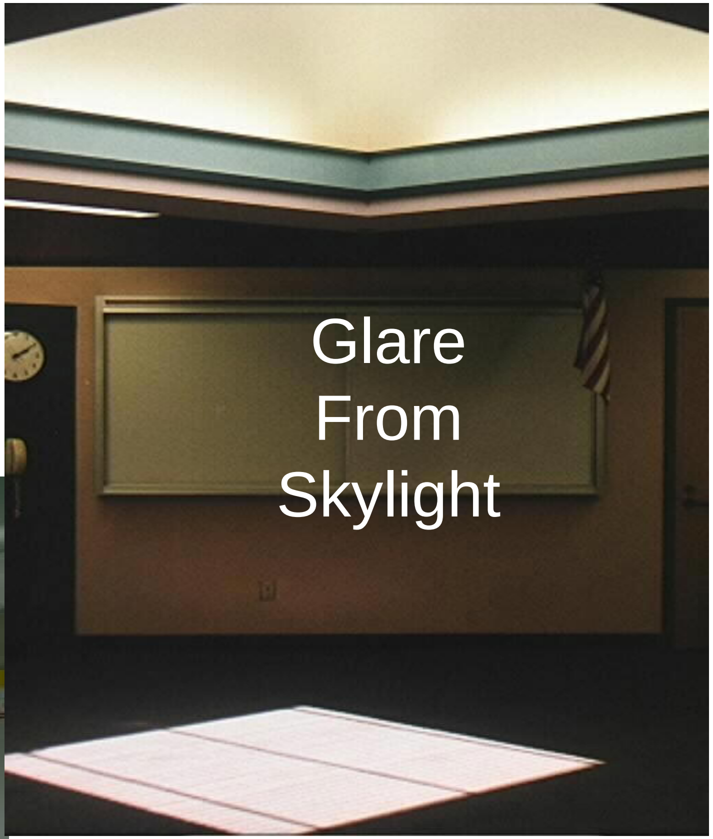
Direct beam *sunlight*

- Strong: up to 10,000 footcandles
- Too bright.
- Too hot.
- Creates glare.

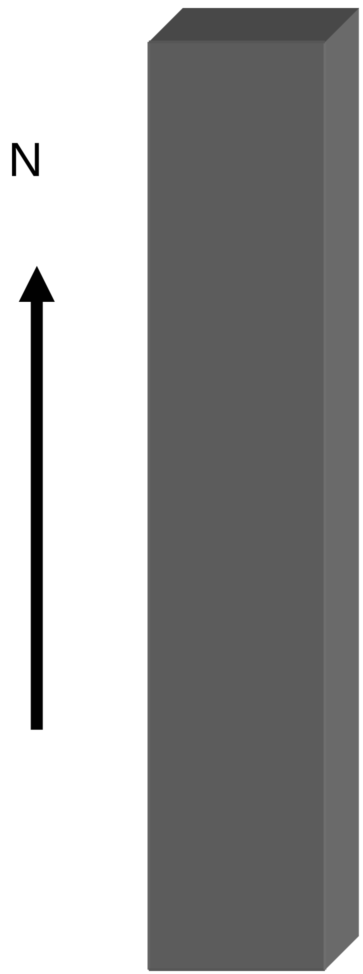
Controlling direct beam:

- Prevent sunlight penetration anywhere people can't move away from it.
- Spread beam over white surfaces such as ceiling to diffuse.
- Sunlight "patches" can pleasantly animate circulation spaces.

Direct beam creates glare…



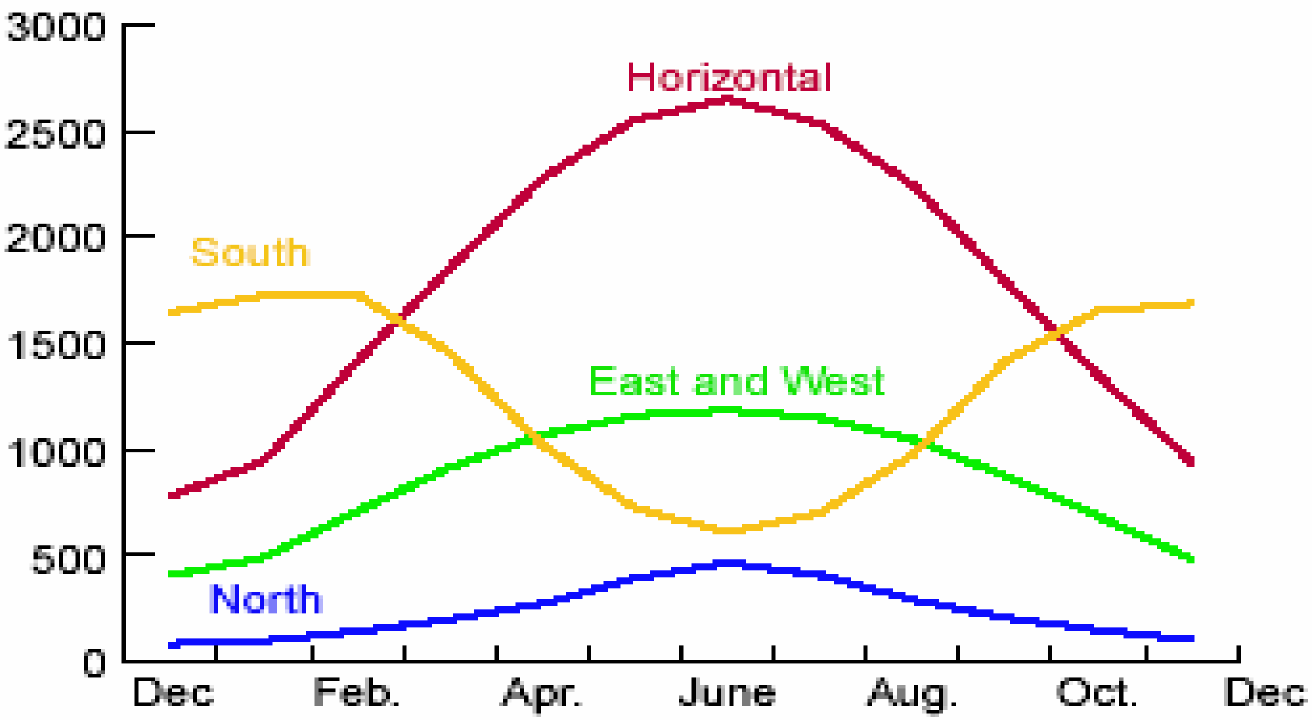
Basic principles of solar orientation



Worst Exposure

- North and south ends provide minimum interior light
- East and west sides tend to introduce too much light and heat
- East and west sides require complex shading systems
- Shading often requires blocking view glazing

Solar radiation varies with surface orientation



Comparison of Window Orientations — 40° Latitude

The amount of solar radiation striking windows varies with the surface orientation.

Minimize east and west-facing glass

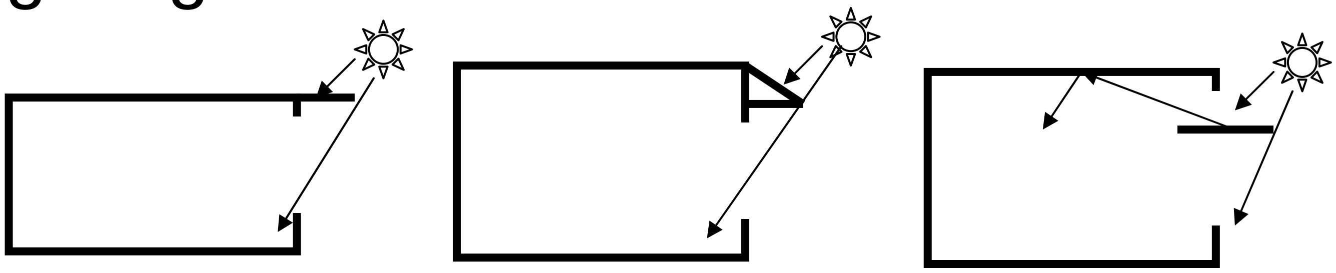
Basic principles of solar orientation

Ideal Exposure

- North side can introduce a maximum of diffuse daylight
- South side can be passively shaded most of the year without blocking view glazing
- East and west sides can have minimal fenestration

Daylighting schemes

Sidelighting

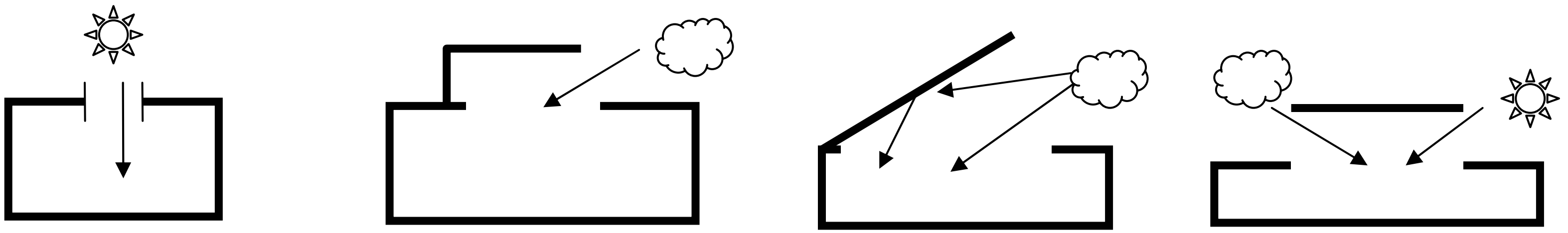


Window w/ Overhang

Window w/ shading

Window w/ light shelf

Toplighting



Skylight

Clerestory

Sawtooth clerestory

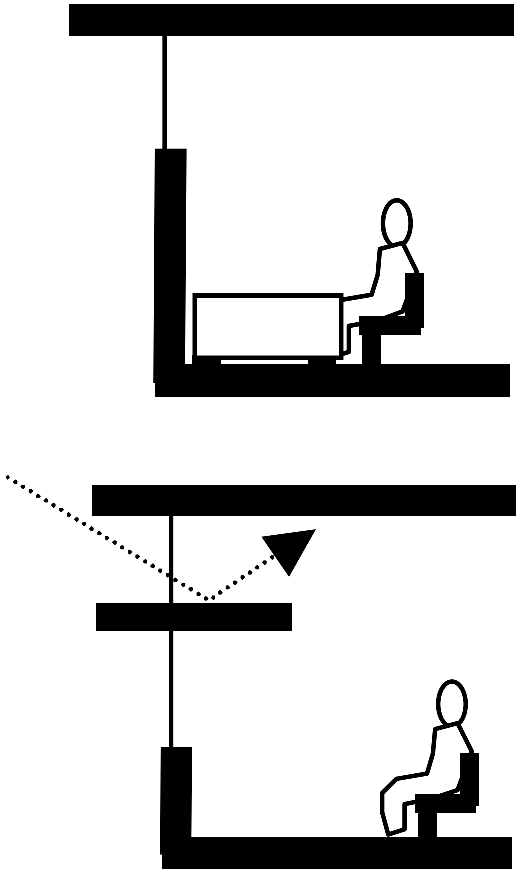
Monitor

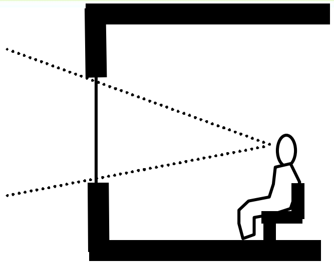
Clerestories

- Clerestories can be used in all school spaces to provide deep penetration of daylight.

Clerestories – with or without light shelves

- A light shelf is a horizontal panel placed below high clerestory glazing (generally with a view window below it) that improves light distribution.
  - Daylight reflects off top surface onto the ceiling.
- Use light shelves or louvers to improve daylight distribution, block direct sun penetration, and minimize glare.



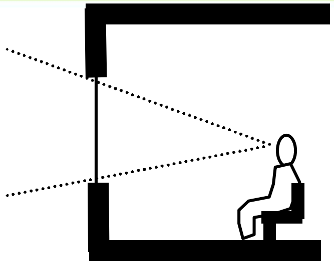


View windows

View windows provide:

- Connection with outdoors
- Emergency egress
- Natural ventilation

View windows



View vs daylighting:

- View windows are often inefficient at supplying working daylight
- However, areas where many buildings will be multi-story, side lighting is the only option for lower floor spaces and should be designed to provide as much useful daylight as possible with the least problematic glare.

Design goal:

- Provide access to exterior views through view windows for all interior spaces where students or staff will be working for extended periods of time.

Skylights

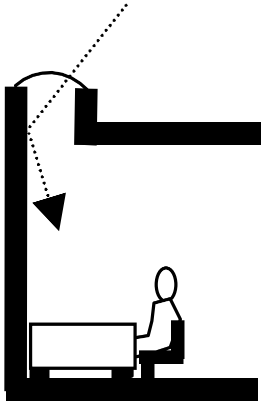
- Proper sizing needed
- Modern skylights using prismatic refractors and other technologies help control glare
- Skylights are:
  - Effective all day long
  - Effective under sunlight or cloudy skies
  - Comparatively inexpensive
  - Relatively independent of building orientation

Skylights in middle school

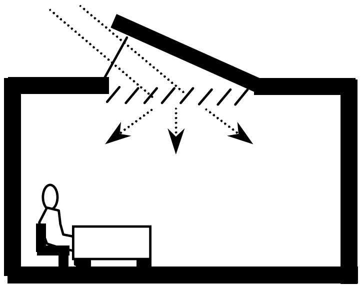
Skylights in high school conditioning center

Wall wash top lighting

- Use wall wash top lighting for interior classroom walls to balance daylight from window walls, brighten interior classrooms, and make them seem more spacious.



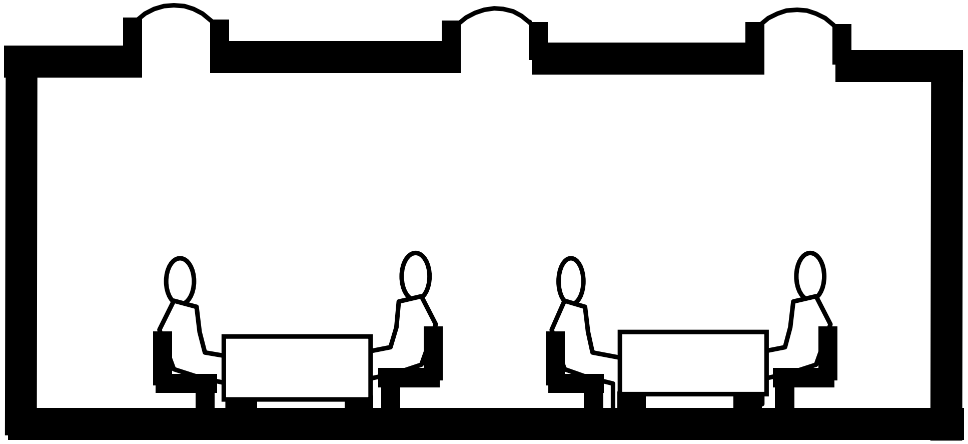
Central top lighting



- Central top lighting is accomplished by a central monitor or skylight (or cluster of skylights) that distributes daylight evenly across the room.

Patterned Top Lighting

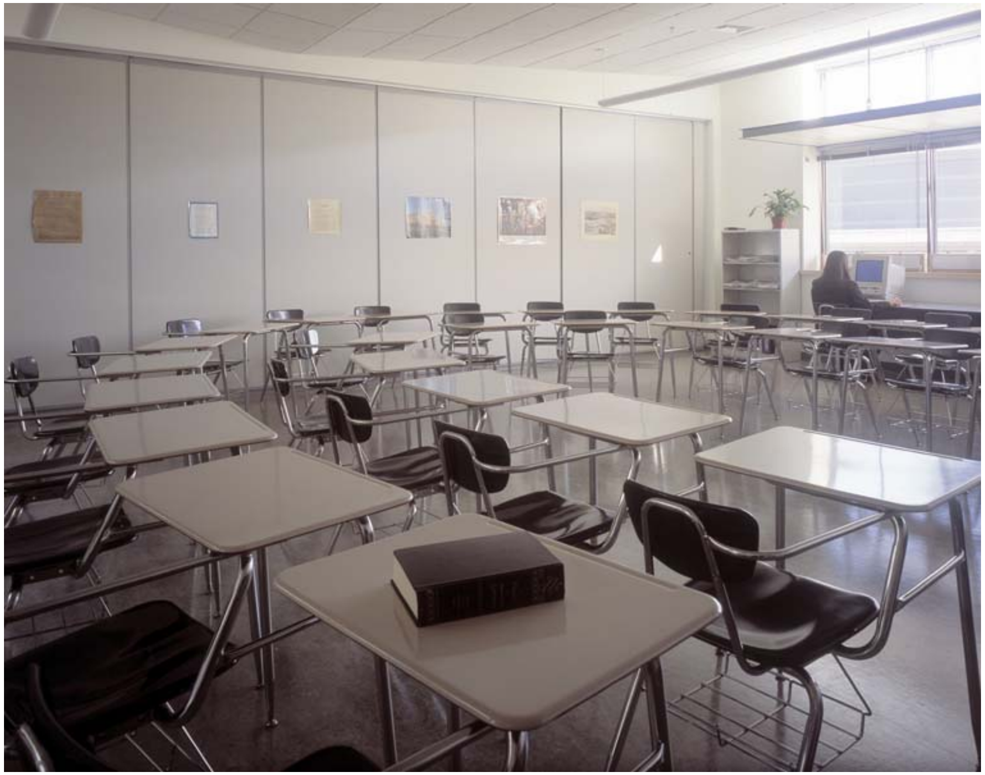
- Use patterned top lighting in interior spaces that need even, low glare illumination across large areas like gyms, cafeterias, and libraries.



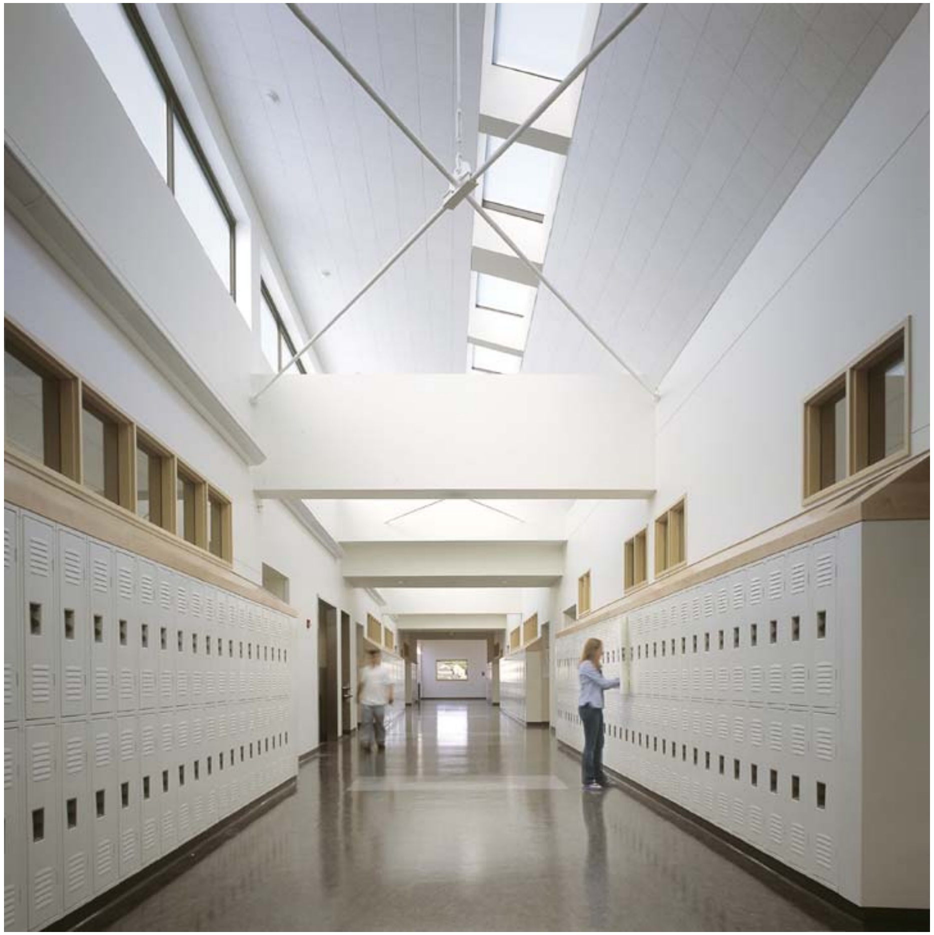
Daylighting examples

Daylighting on both sides

Integrated sidelighting



Top lighting



Sidelighting

Harmony Library in Fort Collins, CO

- 31,000 square feet
- Relatively sparse glazing, all of which is vertical
- No skylights, plenty of monitors
- Highest Tv is 0.38, vision windows 0.18
- Cost of building \$95/ft^2; annual elect costs \$0.65/ft^2, less by 30%+ than other similar buildings on campus

Overhang details

Integrated Daylighting design

Visual transmittance

Modeling is indispensable

Designing effective daylighting is complicated, but worth it!

Daylighting performance is influenced by:

- Glazing size & placement
- Glazing properties
- Paint selection
- Slope of ceiling
- Classroom dimensions

How can you optimize all those variables?

Use a **scale model** or **computer model** to inform design

Scale models

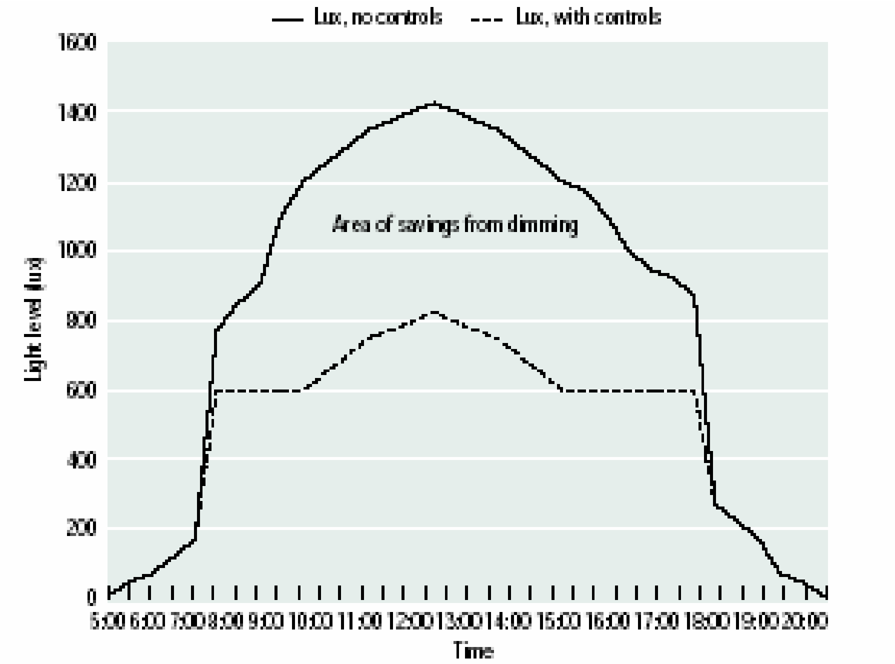
- Unlike thermal models which must be full scale, daylighting models can be accurate if scaled down
- Classroom modeled with different tactics
- Can be moved in relationship to the sun to show daylighting effects under all circumstances
- Photosensors and cameras aid design process

Computer models

- Use to "tune" design for optimal performance
- Easy to try a range of properties
- Use results to select optimal properties for paint, glazing, etc

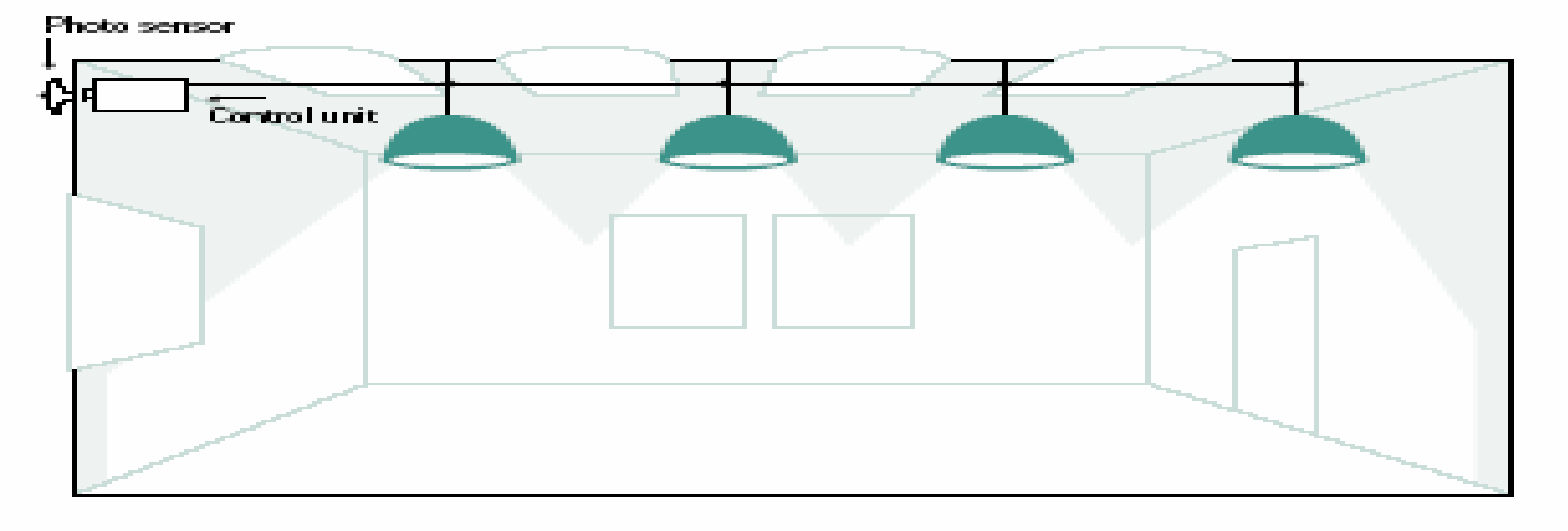
Dimming

- A necessary condition for an effective Daylighting system
- Dimmable electronic ballasts are cost effective
- Well-designed systems respond to sunlight and occupancy



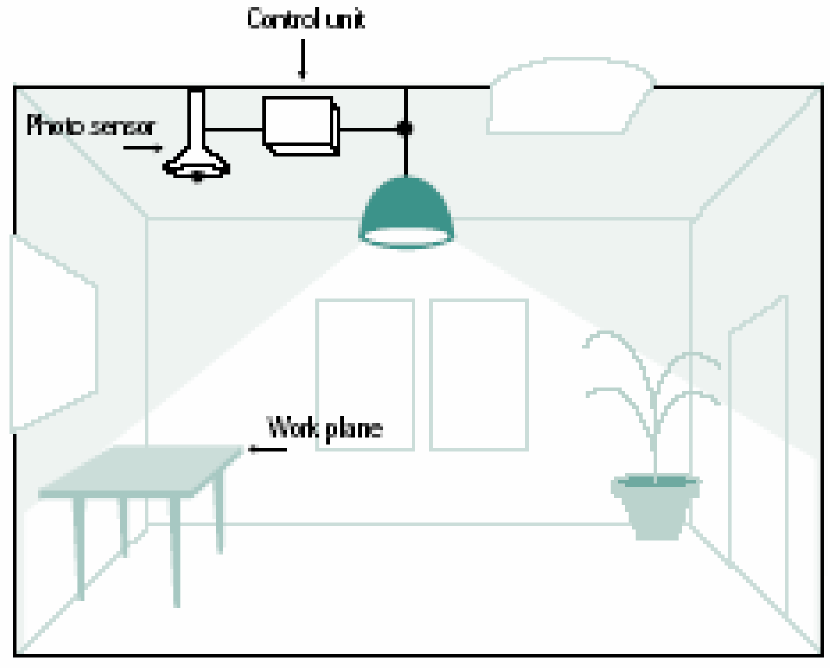
Open loop dimming

- Least expensive dimming option
- Many lights may be dimmed with a single simple sensor that senses only exterior light
- Applicable in atria, gyms, meeting areas



Closed loop dimming

- Sensor monitors natural and electric light, dims electric to set point
- Applicable in classrooms and offices
- Systems are improving, becoming simpler and less expensive



Final notes

- Daylighting designs should be accomplished in coordination with other aspects of the building in a holistic fashion
- Daylighting modeling is a must!
- It is tempting to overdo apertures (windows, skylights), but this increases envelope losses and may increase energy use needed to offset increased thermal loads in all seasons
- Tune window selection: Specify window properties based on location and function
- Good design will allow for excellent lighting, downsized HVAC equipment, and lower energy/demand costs forever